

SHOULDER PAIN IN COMPETITIVE TEENAGE SWIMMERS AND IT'S PREVENTION: A RETROSPECTIVE EPIDEMIOLOGICAL CROSS SECTIONAL STUDY OF PREVALENCE

Monica Tessaro¹

Giorgio Granzotto²

Antonio Poser³

Giuseppe Plebani⁴

Alex Rossi⁵

ABSTRACT

Background: The term "swimmer's shoulder" was first introduced in 1974 by Kennedy and Hawkins to describe a common condition among competitive swimmers characterized by pain and dysfunction of the shoulder complex. Currently, the term does not define a specific clinical diagnosis and its etiology is considered to be multifactorial. In the literature shoulder pain prevalence varies according to the adopted definitions (from 3% to 91%); however, in the Italian environment there is no prevalence study regarding swimmer shoulder. Prevention by means of dry land activities may assist in delimiting shoulder pain in swimmers.

Purposes: The purpose of this study was to investigate the prevalence of swimmer's shoulder over the prior 12 months among teenage athletes and the preventive activities carried out across different sport's teams. A second purpose was to determine whether the extent of the condition is affected by dry land preventive activity. And finally, to compare different preventive activities related to the prevalence of swimmer's shoulder.

Study design: Retrospective epidemiological cross-sectional study of prevalence

Methods: Athletes from four levels of training: Esordienti A, Ragazzi, Juniores and Cadetti (according to Italian Swimming Federation F.I.N.'s partition age) belonging to eight Italian swimming teams and their respective coaches were involved in this study. Two types of questionnaires were created and completed by both the athletes and their coaches during May 2015. The collected data were analyzed by means of descriptive and inferential statistics.

Results: Shoulder pain prevalence over the previous 12 months from the completion of the survey was 51%. In six out of eight of the societies a specific shoulder dry land warm-up was carried out before water training, whereas among seven out of eight societies also utilized weekly sessions of performance (physical) training. Statistically significant differences were noticed between shoulder pain and gender, weekly frequency and duration of dry land warm-up and duration of physical training.

Conclusion: The results of the current study indicate that shoulder pain is prevalent in youth swimmers (51%) and appears to be affected by dry land preventive activities. A weekly frequency of dry land warm-up more than five times appeared to protect swimmers from pain ($p=0.044$); whereas, a dry land warm-up duration greater than 10 minutes seems to cause shoulder pain ($p=0.043$). A single physical training duration lower than 45 minutes seems to be associated with pain ($p=0.035$).

Levels of evidence: 3a

Key words: Dry land warm-up, prevention, shoulder pain, swimmer's shoulder

CORRESPONDING AUTHOR

Monica Tessaro

Valdo Salute, Valdobbiadene, Treviso, Italy,
+ 393496692858

E-mail: monicatessaro93@gmail.com

¹ Valdobbiadene, Treviso, Italy

² ULSS 2 Marca Tevigiana, Treviso, Italy

³ University of Padua, Padua, Italy

⁴ University of Siena, Siena, Italy

⁵ University of Rome "Tor Vergata", Rome, Italy

INTRODUCTION

Swimmer's shoulder

The term "swimmer's shoulder" does not define a specific clinical diagnosis, but rather indicates a typical condition among competitive swimmers characterized by pain and dysfunction of shoulder complex.¹ This term was first used in 1974 by Kennedy and Hawkins to describe a common and painful syndrome of repeated shoulder impingement in swimmers.² Furthermore, this definition specifies that the pain is referred to the anterior area of the shoulder during or at the end of training, compromising athletes' performance during competitions.³

According to a study published in 1974,² the prevalence of shoulder pain in swimmers was 3% whereas in more recent publications the percentage has increased up to 91%. The considerable gap between the two figures lies both in the difference between the underlying assumptions used to establish the definition of the painful event and also in the different inclusion and exclusion criteria adopted. At present, a clear consensus is lacking regarding the causes of shoulder pain in swimmers and the etiology of swimmer's shoulder is considered to be multifactorial.³

Kennedy and Hawkins originally suggested that this syndrome was caused by repetitive primary shoulder impingement (outlet impingement) of the supraspinatus tendon and/or the long head of biceps tendon under the anterior inferior one third of the coracoacromial arch coupled with recurrent episodes of avascularity of these two tendons.^{3,4,5} However, there is no evidence suggesting that the incidence of primary impingement is greater in the swimming population than in the ordinary population.⁵

Two authors subsequently differentiated primary from secondary impingement (or "non-outlet impingement").^{3,6} Secondary impingement can be defined as impingement secondary to the instability of the glenohumeral joint (GHJ). The term "instability" is referred to any structural or functional deficit in the GHJ leading to pathologic motion of this joint. Instability can be defined also as a symptomatic laxity.⁵ Factors contributing to the development of swimmer's shoulder include: neuromuscular system alterations, joint overload, muscular soreness

and imbalances, excessive or reduction of flexibility, biomechanics of swimming, style technique and training mistakes.^{3,7,8} To date, GHJ laxity is no longer considered as one of the most important etiological factors.⁷

Prevention of swimmer's shoulder

Several authors have suggested that prevention programs based on dry land activities should be employed in order to reduce risk factors in predisposed subjects and to restrict the pathology's onset in the other subjects.^{3,9,10,11} In a systematic review, the authors suggested that prevention may be especially important for collegiate freshman swimmers who in their early eligibility years are unaccustomed to the considerable collegiate level yardage that is required, and appear to be more prone to injury.¹¹ This conclusion agrees with the study result of Bak et al who found that the main factor in the development of swimmer's shoulder seems to be the high training volume during adolescence without an organized dry land training program which affects muscular balance of the shoulder complex.⁸ The proposed preventative activities include the training of strength, resistance, balance, muscular flexibility and stability, the improvement of proprioception and neuromuscular control, and the correction of swimming technique.

It is important to point out that warm-up should not lead to muscular fatigue because performance may be compromised. Several authors have investigated the use of warm-up for preventing injuries but there is a lack of studies regarding warm-up effectiveness in swimming.^{12,13} A recent systematic review also pointed out the lack of research into prevention programs in non-contact sports (such as swimming) and their effect on upper extremity injuries.¹⁴ Recent authors have indicated that pre or post-exercise static muscle stretching in different sports neither reduces delayed-onset muscle soreness (DOMS) in young healthy adults,¹⁵ nor prevents injuries¹⁴ or improves performance.¹⁶ Stretching can be effective for people subject to serious muscular stiffness.¹⁵ Furthermore, there is strong evidence that high load dynamic warm-up enhances upper body and strength performance through sport specific movements in different sports.¹⁶ A recent systematic review and meta-analysis shows that strength

training seems to reduce muscle skeletal injuries to less than one third, but no one of the included randomized controlled trials studied a swimmers population.¹⁴ Despite the lack of evidence related directly to swimming, multiple types of warm-up programs may be useful for swimmers.

Painful shoulder biomechanics in swimmer

In 1991 Pink et al conducted an electromyographic and cinematographic analysis of the normal freestyle stroke and studied the main differences in muscular activity between the painful shoulder and the non-painful shoulder.^{4,17} The observed changes of the phases of the stroke were at first considered as a direct effect of the attempt to avoid Neer's sign.⁴ However, another study's authors stated that it is unknown whether the stroke alterations seen in painful swimmers are the cause or a consequence of the pain.¹⁷ Specifically, in swimmers with painful shoulders the main difference in muscle action was markedly lower serratus anterior activity during middle-pull through resulting in shoulder instability and in compensatory use of the rhomboids.⁴ Although this is not the only way to limit shoulder instability, these two muscles are designed to function antagonistically so when the rhomboids contract, the direction of pull is directly opposed to that of the serratus anterior, causing asynchronous muscle action and poor steering of the scapula which affects GHJ stability.⁴ Another asynchrony is related to the decrease in activity of the subscapularis during mid-recovery and an overall general increase of activity of the infraspinatus muscle.⁴ Similar to the serratus anterior, the subscapularis is susceptible to fatigue because of its continual activity in swimmers. Moreover, the subscapularis may decrease its function to avoid the painful degree of internal rotation required during the freestyle stroke. During hand entry in swimmers with painful shoulders, there is a decrease in activity of the anterior and middle deltoids and in the upper trapezius and rhomboids; at hand exit there is also a reduction in activity of the two heads of the deltoid. This reduced activity is related to the dropped elbow position seen during recovery which is one of the hallmark signs of injury. The dropped elbow allows the swimmer to decrease the degree of humeral internal rotation in order to avoid pain and lets the swimmers enter

the water with a wider hand entry.⁴ The swimmer with shoulder pain may present an asymmetric pull: the painful arm may not generate forces equal to the contralateral side causing difficulties in staying at the center of the lane and consequently leading to compensation by decreasing the pull on the contralateral side or by changing the beat of the kick. In order to recognize this painful condition, it is important to pay attention to other signs such as the early hand exit and the excessive body roll.⁴

In subsequent years, other studies by Pink and Ruwe analyzed the electromyography and cinematographic activity of the painful shoulder related to butterfly stroke and to breaststroke finding similar pathological signs.¹⁷

Despite a many studies regarding differences in muscular activity and stroke biomechanics between athletes with painful and non-painful shoulders, a cause and effect relationship between these two elements cannot be inferred.¹⁷ However, most believe that shoulder pain is mainly a biomechanical problem due to muscular dysfunction and imbalances. Therefore, the purpose of this study was to investigate the prevalence of swimmer's shoulder over the prior 12 months among teenage athletes and the preventive activities carried out across different sport associations. A second purpose was to determine whether the extent of the condition is affected by dry land preventive activity. And finally, to compare different preventive activities related to the prevalence of swimmer's shoulder.

METHODS

Study design

This was a retrospective observational study. It was achieved through the creation and completion of questionnaires by competitive teenage swimmers belonging to different sports teams and categories, and their coaches.

Setting

Eight Italian competitive sports teams affiliated with the Italian Swimming Federation (F.I.N) participated in the study. There were 274 athletes affiliated with these teams. Before the survey distribution, authorizations from all sport's teams' presidents were obtained. Each participant agreed

to personal data processing and signed the form in compliance with the Italian Legislative Decree no. 196 dated 30/06/2003. In May 2015 the paper questionnaires were delivered personally to one coach for each sports team who allocated them to their athletes. After three to four weeks as arranged with the coaches, the questionnaires were collected and withdrawn by the author.

Participants

The inclusion criteria for questionnaire assignment were: competitive swimmers belonging to any of the following four categories of Italian swimmers: Esordienti A, Ragazzi, Juniores and Cadetti. These categories are defined according to F.I.N.'s partition age: Esordienti A= Males (M) 12-13 years old, and females (F) 11-12 years old; Ragazzi= M 14-16 years old, and F 13-14 years old; Juniores= M 17-18 years old, and F 15-16 years old; and Cadetti= M 19-20 years old, and F 17-18 years old. All subjects (athletes and trainers) agreed to allow personal data processing giving their informed consent. Athletes belonging to other categories were excluded; as were as athletes with previous history of injury that required a following operation to one or both shoulders before the survey.

Variables

The questionnaire for the athletes was organized into five sections: 1) the study introduction letter; 2) the form for informed consent in compliance with the Italian Legislative Decree no. 196 dated 30/06/2003; 3) personal and anthropometric data (name, date of birth, gender, weight, height), swimming data and training data (years of competitive swimming, specialty, weekly frequency and duration of training, weekly volume) and other sports data (current or past practice of other sports, level, years of practice, weekly frequency, duration training); 4) shoulder pain prevalence and characteristics of pain (number of events, work load, side, age at the first or unique event, period of the last event, training phase, numerical pain scale (NPRS) regarding pain intensity, stroke, objects, consequences, pain reliefs); 5) shoulder pain prevention strategies utilized (dry land warm-up and general physical training and information regarding prevention exercises usefulness).

The questionnaire for the coaches was organized in three sections: 1) the study introduction letter; 2) personal data (name, society name, years as coach), training data (trained categories, range of age trained, weekly frequency, duration and volume of the training and weekly volume); 3) six questions regarding: warm-up activity (mobilizations/ overhead activities/stretching/muscular strengthening) and their characteristics (frequency, duration) and the reasons if they were not performed; physical training (period of practice, weekly frequency, duration, presence of a physical trainer); the most common stroke used during training; the need for changing programs because of shoulder pain experienced by swimmers; eventual drop out from competitions due to shoulder pain; the overall knowledge about "swimmer's shoulder".

Bias

The questionnaires were pilot tested with two athletes and two coaches in advance to assess their understandability. After analyzing the contributions of the pilot subjects, three questions were adjusted. All athletes filled out the questionnaires in the same month during the survey to avoid possible differences regarding the training session and competitions.

This study could present a selection bias: the questionnaire was assigned to all athletes of the eight sport's teams but there were different rates of compliance among the eight teams. Moreover, some sport societies may have chosen only the strongest athletes to be part of the team. For these reasons, the results of this study sample may not be representative of all swimmers.

Extent of the study

Statistical methods

Data was managed and processed in an Excel spreadsheet. The Analysis Tool Pak that the application provides was used to conduct both descriptive and inferential statistics. The sample used for the main analysis of causality between pain and different training variables consists of a total of 166 observations. The sample has been divided in two sub-groups where the discriminant is the presence of pain versus no pain. The sub-group size is of 87 and

Table 1. Athletes' rate of compliance specific for each sport society (sports team) and athletes' number divided into Italian Swimming Federation (FIN) categories.

Society	Participating athletes	Total athletes for each society	Rate of compliance	Esordienti A	Ragazzi	Juniore	Cadetti
Society 1	30	39	76.92 %	12	14	4	0
Society 2	30	44	68.18 %	13	7	8	2
Society 3	45	55	81.82 %	0	29	11	5
Society 4	12	20	60.00 %	6	5	1	0
Society 5	7	24	29.17 %	5	2	0	0
Society 6	9	9	100.00 %	9	0	0	0
Society 7	42	46	91.30 %	18	14	5	5
Society 8	22	37	59.46 %	9	6	4	3
TOTAL	197	274	71.90 %	72	77	33	15
Society= Sports Club of the Italian Swimming Federation							

79 observations respectively. The Student's T-Test was used to investigate differences between groups.

The T-Test was performed under the hypothesis of unpaired samples with different variances. The alpha value was set at $p < 0.05$, as is commonly accepted in scientific publications.

RESULTS

274 athletes were recruited for the participation and received the questionnaire; 204 completed it. Seven of those were excluded from the analysis because one of them was filled out illegibly and the remaining six had been completed by athletes belonging to not-included categories. Thus 197 questionnaires were included in the survey and used for statistical analysis. The rate of athletes' compliance was 71.9% (197/274) (Table and Figure 1). All 19 coaches that were solicited participated in the study, for a response rate of 100% (19/19).

Athletes sample description

The sample consisted of 54.82% females and 45.18% males. The average age and its standard deviation (\pm) was 14.01 (± 2.12) years. The average BMI was 18.96 (± 2.42). According to F.I.N. categories the sample was composed of 36.04% Esordienti A, 39.09% Ragazzi, 17.26% Juniores and 7.61% Cadetti. Regarding the complete sample, the average number of

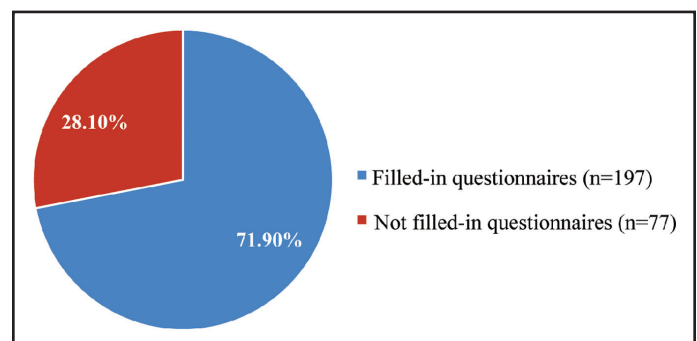


Figure 1. Athletes general rate of survey completion.

weekly training sessions was 5.27 (± 0.81), with 2.12 (± 0.28) hours for each training session, and 25.31 (± 9.02) kilometers per week (Tables 2 & 3).

Coaches sample description

The average years of participation in coaching for the coaches was 10.5 (± 6). They were distributed between societies: two coaches for Society 1, three coaches for Societies 2-3, one coach for Society 4, two coaches for Societies 5-6-7 and four coaches for Society 8.

Prevalence of shoulder pain

The total sample prevalence of shoulder pain related to the 12 months prior to the questionnaires' compilation was 51% (101/197): 51% belonging to Esordienti A, 47% to Ragazzi, 67% Juniores and

Table 2. Training frequency and volume related to categories, reported by athletes.

	Training frequency/week	Training duration (hr)	Weekly volume (km)	Years of competitive practice
Esordienti A	4.74 (± 0.76)	1.93 (± 0.24)	17.71 (± 5.42)	3.95 (± 1.96)
Ragazzi	5.56 (± 0.61)	2.20 (± 0.25)	27.75 (± 7.14)	6.54 (± 2.12)
Juniors	5.52 (± 0.82)	2.23 (± 0.25)	31.23 (± 8.23)	8.70 (± 2.49)
Cadetti	5.80 (± 0.54)	2.27 (± 0.19)	34.36 (± 6.86)	11.00 (± 2.03)
TOTAL SAMPLE	5.27 (± 0.81)	2.12 (± 0.28)	25.31 (± 9.02)	6.27 (± 3.03)
Esordienti A= males 12-13y, females 11-12y, Ragazzi= males 14-15-16 y, females 13-14y), Juniors= males 17-18 y, females 15-16y, Cadetti= males 19-20y, females 17-18y.				

Table 3. Training frequency and volume related to categories reported by coaches.

	Training frequency/week	Training duration (hr)	Distance for a single training (km)	Weekly volume (km)
Society 1	7.25 (± 1.25)	2 (± 0)	6.00 (± 0)	35.00 (± 0)
Society 2	4.33 (± 0.47)	1.83 (± 0.24)	3.67 (± 1.25)	16.33 (± 6.65)
Society 3	8.33 (± 0.24)	2.42 (± 0.12)	6.67 (± 0.62)	41.67 (± 2.49)
Society 4	6.00 (± 0)	2 (± 0)	5.00 (± 0)	30.00 (± 0)
Society 5	6.00 (± 0)	1.50 (± 0)	4.00 (± 0)	20.00 (± 0)
Society 6	4.50 (± 0)	2.25 (± 0)	3.00 (± 0)	14.00 (± 0)
Society 7	5.25 (± 0.75)	2.25 (0)	5.00 (± 0.50)	27.5 (± 7.50)
Society 8	5.75 (± 0.43)	2.13 (± 0.22)	4.83 (± 1.25)	28.25 (± 9.12)
TOTAL	5.94 (± 1.48)	2.10 (± 0.28)	4.85 (± 1.44)	27.22 (± 10.83)
Training frequency and volume related to categories reported by coaches				

40% Cadetti' categories. Moreover, the total sample with pain was composed 56% (61/108) of women and 45% (40/89) of men. With reference to "pain" sample, 71.29% (72/101) showed the symptoms within six months of the questionnaires' completion, 28.71% (29/101) between six months and 12 months of the questionnaires' completion. Sixteen point six percent (16/96) did not experience shoulder pain in the prior 12 months to completion of the survey and 83.33% (80/96) did not ever experience it during their sport career (Table 4). Table 5 reports shoulder pain prevalence related to athletes among sport's teams.

Shoulder pain in relation to anthropometric and sport variables

There was a statistically significant relation between shoulder pain and gender, with females more likely to experience pain ($p = 0.048$). No statistically significant differences were found between shoulder pain and weight ($p = 0.386$), height ($p = 0.273$), BMI ($p = 0.495$) and age ($p = 0.317$). With reference to sport variables, no statistically significant differences were found between pain and years of competitive swimming ($p = 0.479$), weekly training frequency ($p = 0.114$), training duration ($p = 0.161$) and weekly volume ($p = 0.309$).

Table 4. Distribution of pain episodes by categories and interval.					
	Yes, within 6 months	Yes, between 6 months and 12 months ago	No, not in the last year	No, never	% athletes with pain/total category
Esordienti A	24	13	2	33	51% (37/72)
Ragazzi	26	10	8	33	47% (36/77)
Juniore	18	4	3	8	67% (22/33)
Cadetti	4	2	3	6	40% (6/15)
TOTAL	72	29	16	80	
% of painful athlete calculated using the painful population (n=101)	71.29% (72/101)	28.71% (29/101)			
% of non painful athletes calculated using the non painful population (n=96)			16.66% (16/96)	83.33% (80/96)	
% referred to TOTAL population (n=197)	51% (101/197)		49% (96/197)		
Esordienti A= males 12-13y, females 11-12y, Ragazzi= males 14-15-16 y, females 13-14y), Juniores= males 17-18 y, females 15-16y, Cadetti= males 19-20y, females 17-18y.					

Table 5. Pain prevalence among societies.			
Society	No. of swimmers with shoulder pain	No. of athletes totally	Pain prevalence %
Society 1	12	30	40.00%
Society 2	11	30	36.67%
Society 3	19	45	42.22%
Society 4	9	12	75.00%
Society 5	4	7	57.14%
Society 6	7	9	77.78%
Society 7	27	42	64.29%
Society 8	12	22	54.55%
TOTAL	101	197	51.27%
Society= Sports Club of the Italian Swimming Federation			

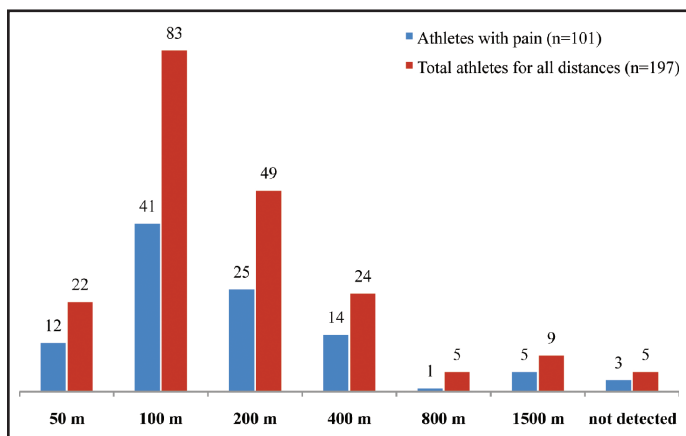


Figure 2. Pain and distance specialty.

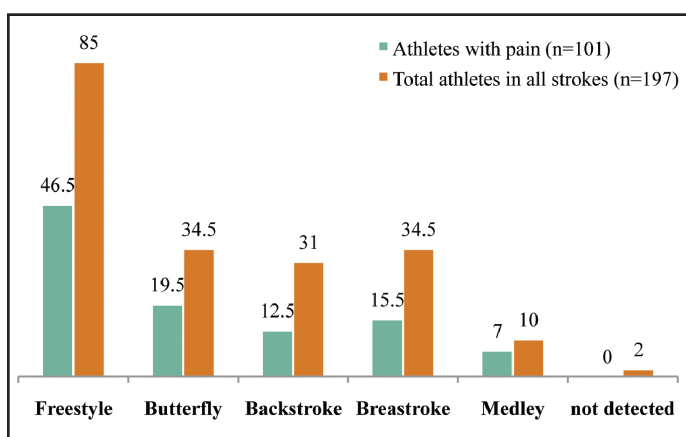


Figure 3. Pain and stroke specialty.

There were no statistically significant differences between pain and the current or past practice of another sport which demands overhead activities (such as volleyball, handball and tennis) in addition to swimming; however, such values approached statistical significance (current overhead sport practice $p = 0.091$; past overhead sport practice $p = 0.106$).

Pain was more frequent in the sprinter swimmers (50 m and 100 m) with a respective prevalence of 12% and 41% (Figure 2). In reference to the swimming specialty the following prevalence of shoulder pain was experienced by the sample of the study: 54.7% freestyle, 56.5% butterfly, 40.3% backstroke, 44.9% breaststroke and 70% medley (Figure 3).

Characteristics of pain

The average number of pain episodes was two to three for the 51% of the subjects in pain sample. In pain

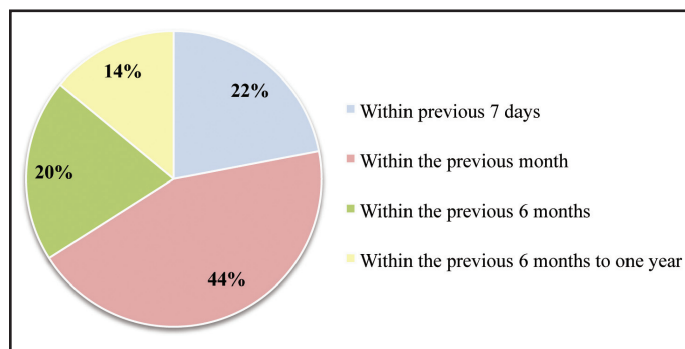


Figure 4. Onset of most recent pain episode.

sample, 31% has been forced to reduce the swimming volume, that is stopping training and/or skipping the following trainings, whereas 69% did not reduce the swimming volume. Pain came out after $4.88 (\pm 2.80)$ years of competitive swimming practice. The unique or the first pain event happened in a specific period of age: 15% at 11 years old, 22% at 12 years old and 16% at 13 years old. The most recent event occurred within one week of the questionnaire's compilation for 22%, within previous month for the 44%, within the prior six months for 20%, and within the prior six and 12 months for 14% (Figure 4). The average duration of the pain episode was 4.5 days (± 10). With regard to the timing of appearance of pain, 10% reported it during warm-up, 27% experienced it during the first half of training and the 47% experienced it during the second half of training, and the residual 16% said it began when out of the water after training.

Shoulder pain intensity during training was evaluated by means of NPRS was $4.58 (\pm 1.71)$, specifically $4.66 (\pm 1.72)$ reported by women and $4.43 (\pm 1.69)$ by men. Regarding stroke type, the pain was produced during freestyle for 52.44%, butterfly stroke for 27.19%, backstroke for 13.04% and 7.33% for breaststroke. Considering the specific phase of freestyle stroke, pain appeared during early-pull-through phase (30.1%), late-pull through phase (27.4%), recovery phase (24%) and glide phase (18.5%) (Figure 5). All coaches stated freestyle as the most frequently performed stroke during training, even if they attempted to train the athletes using all the four strokes. After pain's appearance, 45.33% of the swimmers reported that they would "continue the training even if I would need to stop, but with reduced intensity and effort", 34% stated "I

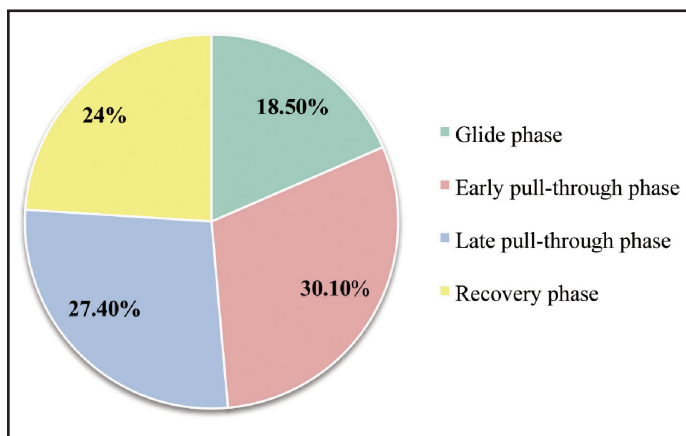


Figure 5. Pain in relation to freestyle stroke phases.

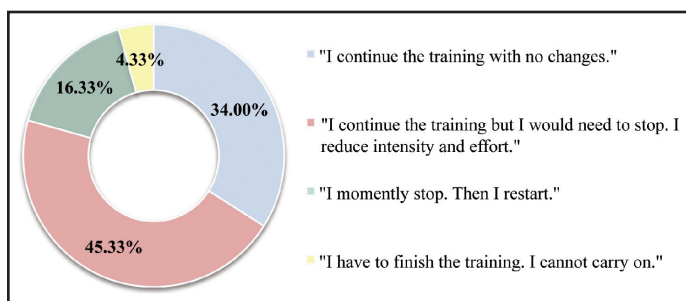


Figure 6. Pain effects on training.

can continue the training with no changes", 16.33% chose "I temporally stop and then I restart" and 4.33% signaled "I have to finish the training as I cannot carry on" (Figure 6). Figure 7 shows the reliefs taken by swimmers to resolve the pain. Moreover,

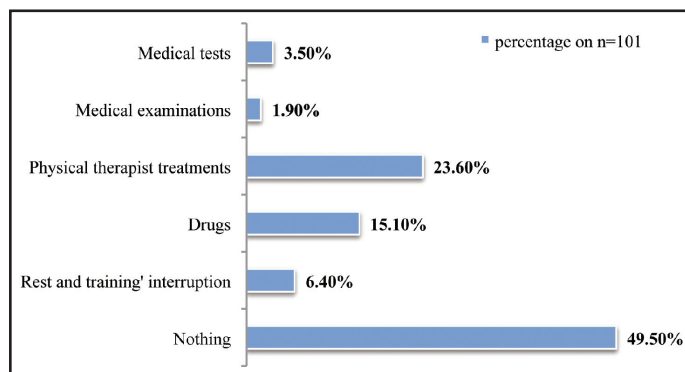


Figure 7. Reliefs for pain.

some athletes reported that their pain was produced or aggravated by the use of hand paddles (13 athletes), elastic bands (14), kick boards (10), and isometric machines (2).

Swimmer's shoulder prevention

Dry land shoulder-specific warm-up carried out before training in the pool was practiced by six out of eight societies included in the study, in particular 155 out of 197 athletes and 14 out of 19 coaches. Dry land shoulder-specific warm-up was carried out an average weekly frequency of 5.79 (± 2.05) times with average duration 20.36 (± 13.02) minutes (Table 6). The lack of dry land warm-up was justified by the coaches of the relevant societies due to insufficient time and the skills of the athletes being inadequate to for correct and efficient performance of the

Table 6. Frequency and duration of dry land warm-up for societies (sports teams).

Society	Weekly warm-up frequency	Average warm-up duration (min)
Society 1	7.25 (± 1.25)	12.50 (± 2.50)
Society 2	NO DRY LAND WARM-UP	
Society 3	8.33 (± 0.24)	13.33 (± 2.36)
Society 4	2.00 (± 0)	60.00 (± 0)
Society 5	NO DRY LAND WARM-UP	
Society 6	4.50 (± 0)	30.00 (± 0)
Society 7	5.25 (± 0.75)	15.00 (± 0)
Society 8	5.00 (± 1.73)	17.50 (± 7.50)
TOTAL	5.79 (± 2.08)	20.36 (± 13.02)
Society= Sports Club of the Italian Swimming Federation		

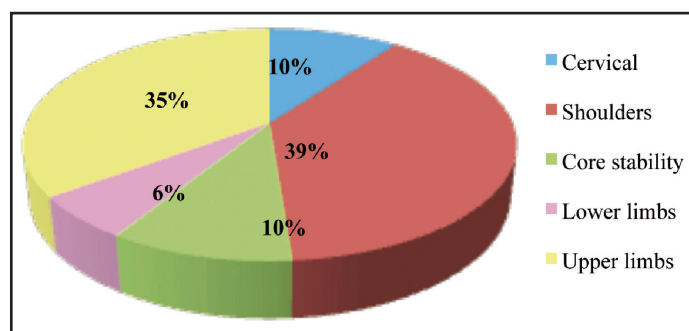
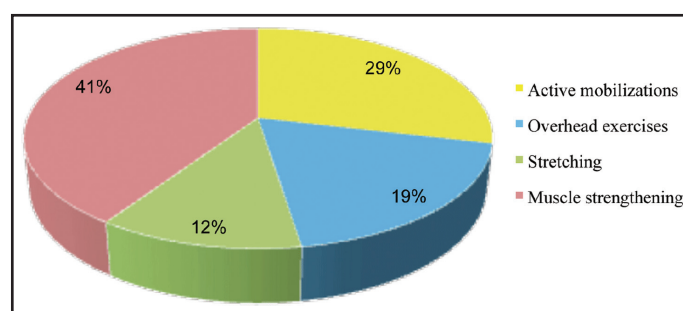
Table 7. Frequency, duration, and timing of physical training for societies.

Society	Weekly physical training frequency	Average physical training duration (hr)	Period	Sports trainer (YES/NO)
Society 1	2.06 (± 0.43)	1.87 (± 1.58)	All season long	Yes
Society 2	2.13 (± 0.80)	1.64 (± 0.47)	All season long	Yes
Society 3	2.00 (± 0.65)	1.23 (± 0.33)	All season long	Yes
Society 4	NO PHYSICAL TRAINING			
Society 5	2.20 (± 0.75)	1.30 (± 0.40)	September	NO
Society 6	1.67 (± 0.47)	1.33 (± 0.47)	All season long	NO
Society 7	2.05 (± 0.94)	1.30 (± 0.42)	September-October	NO
Society 8	2.17 (± 0.37)	1.54 (± 0.38)	September-October	Yes
TOTAL	2.08 (± 0.70)	1.48 (± 0.77)		

Society= Sports Club of the Italian Swimming Federation

exercises. Physical performance enhancement training was carried out by all societies except one at the beginning of the sport season or during the year with an average weekly frequency of 2.08 (± 0.70) times and an average duration of 1.48 (± 0.77) hours. In four out of seven societies coaches were supported by an athletic trainer (Table 7). Dry land program activities were based on the interactions with other coaches/sports trainers/physical therapists 54.8% of the time, on personal research (such as academic studies) 26.2% of the time, and on research material supplied by S.I.T. in 19%.

Figure 8 shows the involved body regions included in dry land warm-up, the core and the lower limbs were the less trained areas during physical training. Figure 9 shows the different warm-up activities;

**Figure 8.** Body regions involved in dry land warm up.**Figure 9.** Activities included in dry-land warm up.

strength training and active mobilization of the shoulders were performed more than stretching and overhead exercises. Finally, 12 out of 19 coaches stated that they were rarely forced to change training programs because of shoulder pain complained of by swimmers, only one coach declared he often changes his training programs and the remaining six coaches never needed to change their training programs because of athlete's shoulder pain.

Shoulder pain in relation to dry land warm-up and physical training variables

Several variables of physical training showed statistically significant differences between the pain sample and the no pain sample. The weekly frequency of warm-up of the pain sample and the no pain one is on average respectively 4.70 and 5.13

($p = 0.044$), indicating that swimmers with a weekly frequency of more than five has less pain. Dry land warm-up minutes differed between the two groups ($p = 0.043$), indicating that a dry land warm-up duration of greater than 10 minutes was associated with greater shoulder pain. Finally training duration of a session was statistically different between groups, ($p = 0.035$), a training duration more than 45 minutes appearing to benefit the athletes. There were no other statistically significant differences in training variables between groups.

DISCUSSION

Shoulder pain in relation to anthropometric and sport variables

The present study observed that the prevalence of swimmer's shoulder was moderate among competitive teenage swimmers, with 51 % of the participating athletes reporting at least one painful event during the 12 months preceding the collection of data. This value is greater than the results of the other international studies published in literature where prevalence ranges between 18% to 38%.^{1,9,18,19} Only Sein et al in their study found a higher prevalence value than the current study, equal to 91%.⁷ The variability of the results can be attributed to the different inclusion and exclusion criteria utilized in the studies; however, another plausible explanation may be athletes' inability (in particular athletes belonging to the younger age categories such as Esordienti A) to differentiate between pain and soreness. It could be important that coaches define and teach this difference and their respective signs and symptoms to athletes in order to make swimmers aware of this condition, and to minimize the potential for cumulative damage as well as hasten the return to sport after an injury as Pink and Tibone stated in their study.⁴

The correlation between shoulder pain and sex was found to be statistically significant for females ($p = 0.048$). This result could be attributed to arm strokes being shorter than those of their male colleagues, which enhances the risk of suffering from an overuse injury due to the higher amount of arm revolutions per lap.³ Although this difference is small for short distances, it becomes significant for long distances, potentially causing major shoulder overload

for female swimmers. Another reason for this statistically significant correlation and for NPRS values regarding shoulder pain intensity which was higher among female swimmers ($4.66 [\pm 1.72]$) than among male swimmers ($4.43 [\pm 1.69]$) could be the different pain perception between sexes²⁰. The literature shows that women have a lower pain thresholds in comparison with men and this seems to be affected by multiple biological (sex hormones) and psychosocial processes.²¹ Although there are described differences in laxity between males and females, it is likely not the major contributor to the multifactorial etiology of swimmer's shoulder.^{1,7,9}

Because the difference approached statistical significance ($p = 0.091$), it could be suggested that practicing another sport in addition to swimming that overloads upper limbs, may promote the onset of pain. To benefit from the effects of cross-training and to prevent the onset of shoulder pain, it may be important to practice a sport or another physical activity which trains strength and core stability or develops aerobic capacity rather than impact sports and sports that use the upper extremities primarily, as Auvinen et al have suggested.²²

In accordance with other publications,^{9,11,18} the results of this study did not demonstrate a statistically significant correlation between shoulder pain and weekly volume of training ($p = 0.309$); which contrasts with the popular opinion that swimmer's shoulder is a consequence of volume of load on the shoulder's complex.

Characteristics of pain

Seventy percent of the total sample experienced shoulder pain one to three times during the 12 months before data collection. The average duration of pain episodes was 4.5 days (± 10) and pain relief strategies used to address the painful episode (49.5% do nothing and 6.4% rest and interrupt training) seem to indicate the self-resolving character of pain, which is likely due to soft tissue inflammation.

The results of this study concur with the findings of Sein et al.⁷ and Tate et al.¹⁹ that specific swimming strokes have little effect in predisposing elite swimmers to shoulder pain and that early pull-through phase and late pull-through phase of freestyle stroke

are the part of the stroke with a high frequency of pain onset (30% during early pull-through phase and 27% during late pull-through phase). It has been suggested that if during glide phase the rhomboids, anterior serratus and upper trapezius muscles are strained or are not recruited with the correct activation timing, they cannot allow a good GHJ stabilization predisposing swimmers to shoulder impingement.¹⁹

Shoulder pain in relation to dry land preventive activities

The lowest percentage of injury was seen in Society (sports team) 2 equal to 36.67% (compared to the average injury percentage = 55.96%); this value approached to critical value equal to 30.12%. Paradoxically Society 2 is one of the two societies that did *not* perform dry land warm-up, although physical training was utilized during the entire competitive season with the participation of a sports trainer. Conversely, Society 5 did not perform dry land warm-up but included physical training in September without participation of a sport trainer; in this case injury percentage was equal to 57.14% (greater than the general average). However, this result could be due to athletes' rate of compliance to respond to the questionnaire which was the lowest one for Society 2 among the eight involved societies. Conversely, Society 4 showed an injury percentage among the highest, (equal to 75%) and this is the only society that did not utilize physical training. Therefore, from this qualitative comparison of data and considering sample differences it can be deduced that physical training represents an element which may significantly affect the onset and prevalence of pain. A separate comment is required for Society 6, which trains only athletes belonging to the Esordienti A category (youngest swimmers), who then move to Society 3 as they reach the adequate age. By comparing injury percentage, it can be noticed that Society 6 presents the highest value equal to 77.78% (rate of questionnaire compliance = 100%) and Society 3 a value equal to 42.22% (rate of questionnaire compliance = 81.82%). The considerable difference may be explained as the younger athletes' difficulty distinguishing pain from soreness, as previously suggested, but also as the consequence of a natural selection according to which only athletes with good

physical condition or a low enough pain are the ones to continue competitive swimming.

From the statistically significant correlations found in this study it appears that considering the quantity of warm-up in terms of both frequency and duration and the quality of warm-up are of fundamental importance. With regard to the statistically significant findings related to physical training, it can be observed that training, apart from swimming may play an important preventative role. Warm-up during physical training should include a general warm-up including activities of moderate intensity which require use of large muscles and that enhance body temperature (such as cyclette or a light run) and a dynamic warm-up specific to activating muscles used in swimming through use of dynamic motions and elastic band exercises (for example: arm revolutions, dry land swimming movements, trunk rotations, internal/external GHJ rotation).²³ From the results of recent studies in different sports (except swimming), static stretching should be performed only in the specific case of stiffness and muscular or capsular shortening as it does not show any protective injury effect, while strength training can improve performance and reduce muscle skeletal injuries.¹⁴

Results of the current study indicate that the core and lower limbs are the less trained areas during physical training; however, it is important to work intensely on core stability since a recent study noticed statistically significant correlations between shoulder pain and a low core performance assessed using the side bridge test, the prone bridge test and the closed kinetic chain upper extremity stability test.¹⁹ Other authors have stated that endurance training of core muscles is an essential component in any injury prevention program.³ Adequate core-stability allows for efficiency during swimming, it facilitates powerful and efficient strokes and kicks without excess energy dispersion, contributes to the production of body rotation in freestyle and backstroke, and manages or controls body undulations in breaststroke and butterfly²⁴. Training of the lower limbs serves a fundamental preventive role as it helps develop an adequate balance with the other elements of the kinetic chain reducing the risk of shoulder overload. This supports the findings of Bak

et al. who stated that it was necessary to associate training in water with dry land training in order to influence muscular balance in particular during adolescence when the athlete's bodies are continuously changing.⁸

Limitations

The main limitation of this study is the questionnaire that was utilized. The authors developed this questionnaire for this research only and did not establish any reliability or validity statistics for it. Some pilot testing was utilized for clarifications, but no further analysis was performed. The structure of the questionnaire did not allow for deeper analysis by inferential statistics related to dry land preventive activities. Secondly, the lack of studies published in the literature regarding the prevention of injuries in swimming or upper limb injury prevention did not allow comparison of the results of this study with other evidence. Finally, as the study specifically excluded former-athletes who left their swimming career due to shoulder pain, it was not possible to examine how or whether this condition led to ceasing competition or training.

CONCLUSION

The results of this study demonstrate that swimmer's shoulder is a prevalent condition among competitive adolescent swimmers and that it is related to by warm-up and dry land physical training practices. Although this study included about 200 competitive teenage swimmers, further investigations are needed to analyze the preventive role of dry land programs on swimmer's shoulder.

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